Report 4084

NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20034

THE EFFECT OF SURFACE PREPARATION AND REPAINTING PROCEDURES ON THE FRICTIONAL RESISTANCE OF OLD SHIP BOTTOM PLATES AS PREDICTED FROM NSRDC FRICTION PLANE MODEL 4125

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by
Eugene E. West

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SHIP PERFORMANCE DEPARTMENT
RESEARCH AND DEVELOPMENT REPORT

May 1973 Report 4084

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Naval Ship Research and Development Center

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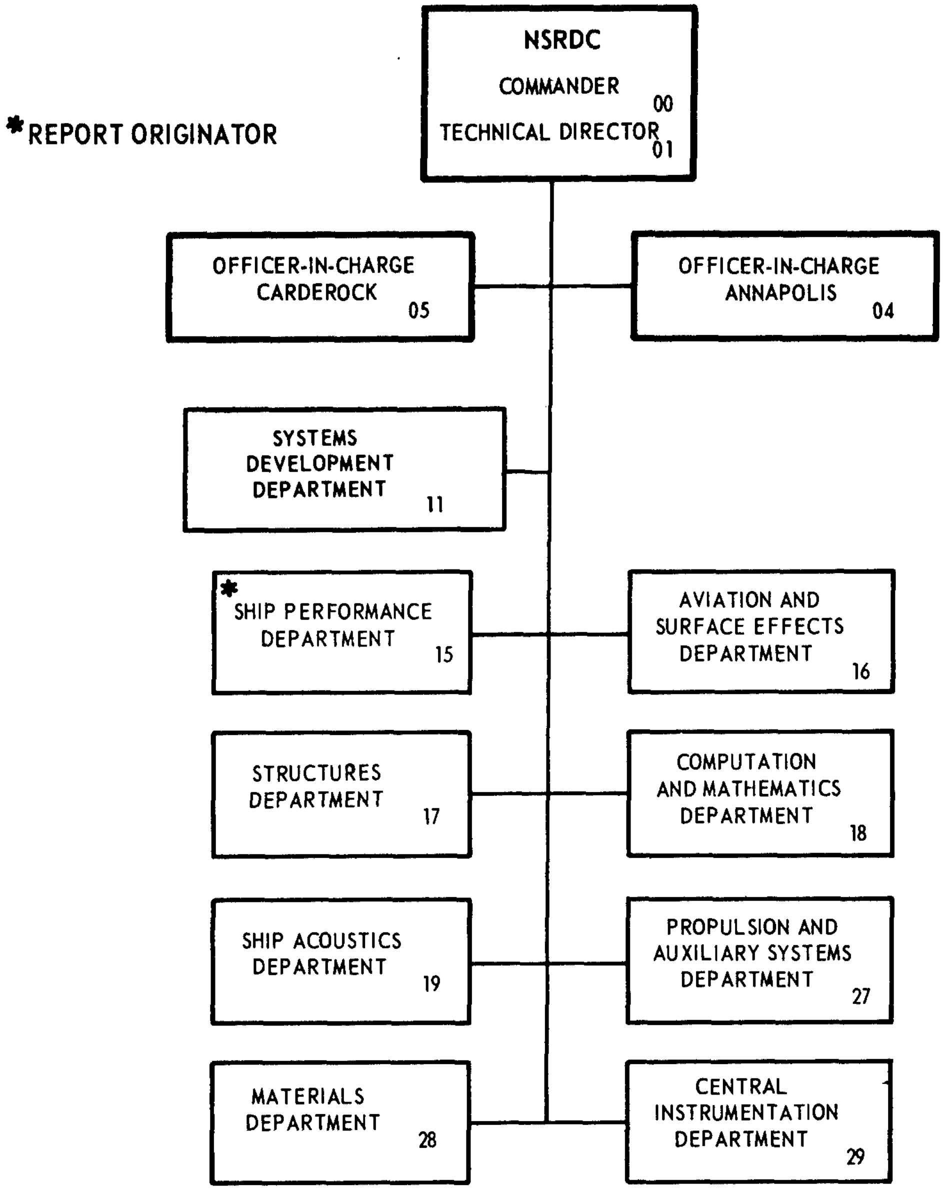

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DEPARTMENT OF THE NAVY
NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER
BETHESDA, Md. 20034

THE EFFECT OF SURFACE PREPARATION AND REPAINTING PROCEDURES ON THE FRICTIONAL RESISTANCE OF OLD SHIP BOTTOM PLATES AS PREDICTED FROM NSRDC FRICTION PLANE MODEL 4125

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ABSTRACT

The Naval Ship Research and Development Center utilized a friction plane (NSRDC Model 4125) to estimate the differences in frictional resistance of two types of antifouling paints and of old ship bottom plates in three surface conditions. Photographs and roughness measurements are included for each surface investigated together with experimental data expressed as values of roughness allowance coefficient versus Reynolds number.

ADMINISTRATIVE INFORMATION

This experimental program was authorized by Maritime Administration Purchase Order P1-MA66-126 of 3 August 1965 and Amendment 1 of 19 January 1967. The present report was prepared under Work Unit 4-1500-001.

INTRODUCTION

The Maritime Administration (MARAD) and Panel 0-23 of the Society of Naval Architects and Marine Engineers (SNAME) collaborated in a program to investigate the effect of ship hull roughness. MARAD requested NSRDC to conduct experiments to aid in evaluating the differences in frictional resistance of the bottom plating from an old ship in three conditions: (1) as taken from the ship in drydock (free of fouling), (2) after wire brushing and normal repainting with MARAD bottom paint, and (3) after sandblasting and application of a complete coating of Navy vinyl paint.

The bottom plates had been taken from the converted Liberty ore carrier OMNIUM CARRIER which was built in 1943. In the period between 1954 and 1965, the bottom of this ore carrier had been sandswept every other year prior to painting; on alternate years, it had simply been washed prior to painting. The ship was drydocked in October 1965 and the bottom was sandswept and painted with one coat of anti-corrosive paint and one coat of antifouling paint. The bottom plates were removed 4 months later (February 1966). Additional information on the ship bottom plates is available from the drydocking company.[1]

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[1]Newport News Shipbuilding and Drydock Company Materials Laboratory Report 3420 (23 Feb 1966). Additional information was reported informally to R. Devoluy, Chairman of SNAME Panel 0-23 in Newport News Shipbuilding and Drydock Company letter dated 1 July 1966.

PROCEDURE

The tests were run in the NSRDC deep water basin utilizing carriage 2. NSRDC friction plane (Model 4125) served as the test vehicle. It is 21 feet long and has a maximum beam of 6.7 inches. For the experiments reported here, it was towed at a draft of 3 feet. Figure 1 indicates the shape and principal dimensions of the friction plane, and Figure 2 shows it at rest and under tow.

The friction plane was painted in turn with MARAD and Navy vinyl antifouling paints and also (at MARAD request) with NSRDC model paint. The MARAD paint was antifouling paint 52-MA-403C; pretreatment included one coat of primer MIL-P-15328B and two coats of brown anticorrosive paint 52-MA-401b separated by one coat of green anticorrosive paint 52-MA-401b. Spraying instructions and drying times were as specified by MARAD. The Navy paint was vinyl red antifouling Type MIL-P-15931A; pretreatment included one coat of primer MIL-P-15328B and four coats of vinyl red lead primer MIL-P-15929A.

NSRDC model paint was applied to the friction plane in the same manner as used to obtain a "Class A" finish on NSRDC models. Experiments conducted in 1951 with the friction plane painted in this manner had indicated that this surface condition is comparable to a smooth, bare metal plate.[2]

Figures 3–5 show the surface finish of these paints on the friction plane. The bolt heads below the waterline were filled before the paint was sprayed and do not show in the photographs.

The painted friction plane was towed up to a maximum safe speed of 13.8 knots (23.3 ft/sec), corresponding to a Reynolds number $R_e = VL / \nu$ of approximately 4.5×10^7.

Following these runs, the friction plane was fitted with fiberglass plates (Figure 6). These represented the ship bottom plates and were made from molds formed from the OMNIUM bottom plating. Mold "A" (hereinafter referred to as Plate A) was taken from the bottom plating as it came from the hull; see Figure 7. Mold "B" (hereinafter referred to as Plate B) was made after the plating had been given the normal treatment for annual drydocking (hand wire brushing followed by the application of one coat of zinc chromate primer, one coat of MARAD anticorrosive paint, and one coat of MARAD antifouling paint); see Figure 8. Mold "C" (hereinafter referred to as Plate C) was made after the plating had been grit blasted to bare metal and painted with the Navy vinyl system (one coat of wash primer, four coats of vinyl red lead, and one coat of vinyl antifouling paint); see Figure 9.

When the friction plane was covered with the fiberglass plates, the towed speed was limited to 11.5 knots (Reynolds number of approximately 4.0×10^7) because the maximum force on the resistance-measuring equipment is 250 pounds.

Panel 0-23 of SNAME had forwarded a BSRA profilometer (Figure 10) for NSRDC use in measuring the comparative surface roughnesses of the paints and plates. However, the 1:1 ratio was not sensitive enough

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[2]Couch, R.B., "Preliminary Report on Friction Plane Resistance Tests of Antifouling Ship Bottom Paints," David Taylor Model Basin Report 789 (Aug 1951).

to measure the difference in paint roughness, and an NSRDC profilometer (Figure 11) was used for this purpose.[3] The BSRA profilometer was utilized to measure the roughness of the ship bottom plates in the three surface conditions.

All resistance data were reduced to coefficient form and treated in the same manner as for previously reported data.[2] It was assumed that experiments with the bare metal (no paint on the friction plane)[2] represented the same condition as the smooth plank friction coefficient C_f of the Schoenherr friction line. Therefore, the total resistance coefficient C_t for the bare metal condition was used as a baseline in determining the "roughness allowance" coefficient ΔC_f for the other conditions. The difference between the various total resistance coefficients compared to that of the bare metal was considered due to the roughness of the paint or plate and was expressed as a frictional "roughness allowance" coefficient.

RESULTS AND DISCUSSION

BSRA profilometer measurements of the plates for the three surface conditions are shown in Figures 12–14. The roughness measurements of the paint surface on the friction plane as made with the NSRDC profilometer are presented in Figures 15–17. For purposes of comparison, Figure 18 indicates a roughness measurement made with the BSRA profilometer at the same points on the friction plane as shown in Figure 16.

The experimental points were converted to resistance coefficients for all paints and plates tested. The total resistance coefficient C_t is expressed as $R_t/(1/2\rho SV^2)$ where R_t is the total resistance, S is the wetted surface of the plates, ρ is the water density, and V is the speed in feet per second. The points shown in Figure 19 represent the actual differences between the measured total resistance coefficients and the faired values for the bare metal experiments. Thus, the zero line corresponds to the bare metal condition.

For several reasons, the roughness allowance coefficient ΔC_f values shown in Figure 19 are comparable only with each other and should not be used to compare correlation allowances obtained from full-scale vessels with the same paint. One obvious reason is that the aluminum plates used on the friction plane were very smooth compared to typical ship bottom plating with its welds, laps, mill scale, and/or pitting. The ship also has scoops, sea chests, and similar appendages that are not fitted to a model. In model experimenting, no correction is made for the effect of moving water through the condensers or the scale effect on appendages such as rudders and struts used on models during experiments.

For example, unless directed otherwise, NSRDC uses a correlation allowance ΔC_f of 0.0002 in friction calculations to expand model experimental data to full-scale predictions for a clean commercial cargo-type

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[3]Eisenberg, Phillip, "Note on Studies of the Resistance of Hydraulically Rough Surfaces," David Taylor Model Basin Report 726 (Sep 1950).

hull operating in smooth, deep sea water with a temperature of 59 F. The value obtained for the friction plane coated with MARAD paint was about 0.00006 (see Figure 19).

Although some detail was lost in the photographs of the fiberglass plates (Figures 7–9), it can be noted that the pit marks or depressions in Plate C were deeper and larger in cross section than those in Plates A or B. Further evidence of this condition is shown in Figure 19. Plate C had the highest resistance of the three sets of plates. Apparently, sand blasting removed rust that had not been removed by other methods of cleaning and caused larger depressions in Plate C.

CONCLUSIONS

1. The degree of roughness measured on Plates A, B, and C caused huge increases in ΔC_f values. Increases of such magnitude should be expected to cause a large increase in the frictional resistance of a ship.

2. The roughness profile of Plates C and the resulting higher values of ΔC_f compared to Plates A and B suggest that sandblasting is not the complete remedy for bringing an old ship bottom back to a satisfactory smoothness.

That treatment removed some heavy rust scale from the pits, and even five coats of vinyl bottom paints failed to level the resulting rough surface. In fact, the surface of Plate C was hydrodynamically rougher than the accumulation of paint layers on the original surface (Plate A).

RECOMMENDATIONS

In view of the substantial investment in this program and the need for more information on how to hydrodynamically recondition rough ship bottoms, it is recommended that additional experiments be conducted on some of the panels retained from the Plate B and C runs. These panels could be rolled and/or sprayed with various high-build coatings which have a proven performance for minimizing underwater corrosion. If profilometer measurements indicate that some of these coatings hold promise for leveling the surface then they could be used to recondition the entire set of C plates for frictional resistance trials.

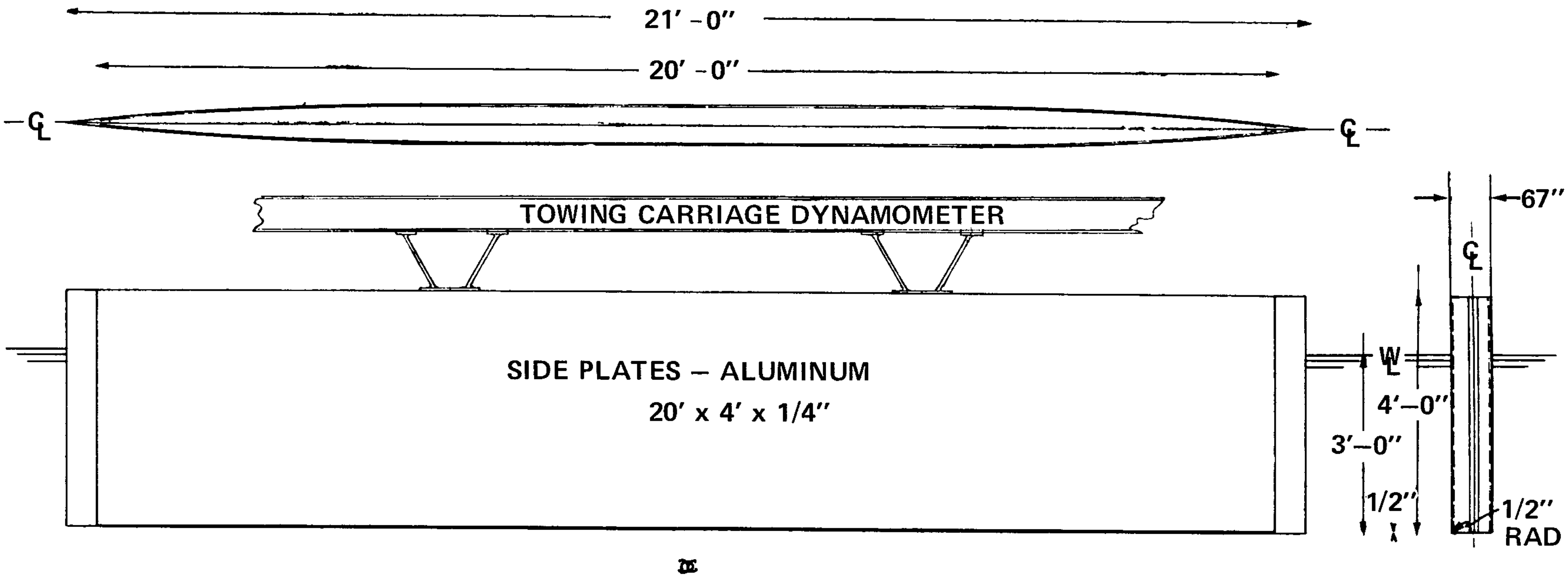


Figure 1 – Details of NSRDC Friction Plane and Connection to Towing Carriage

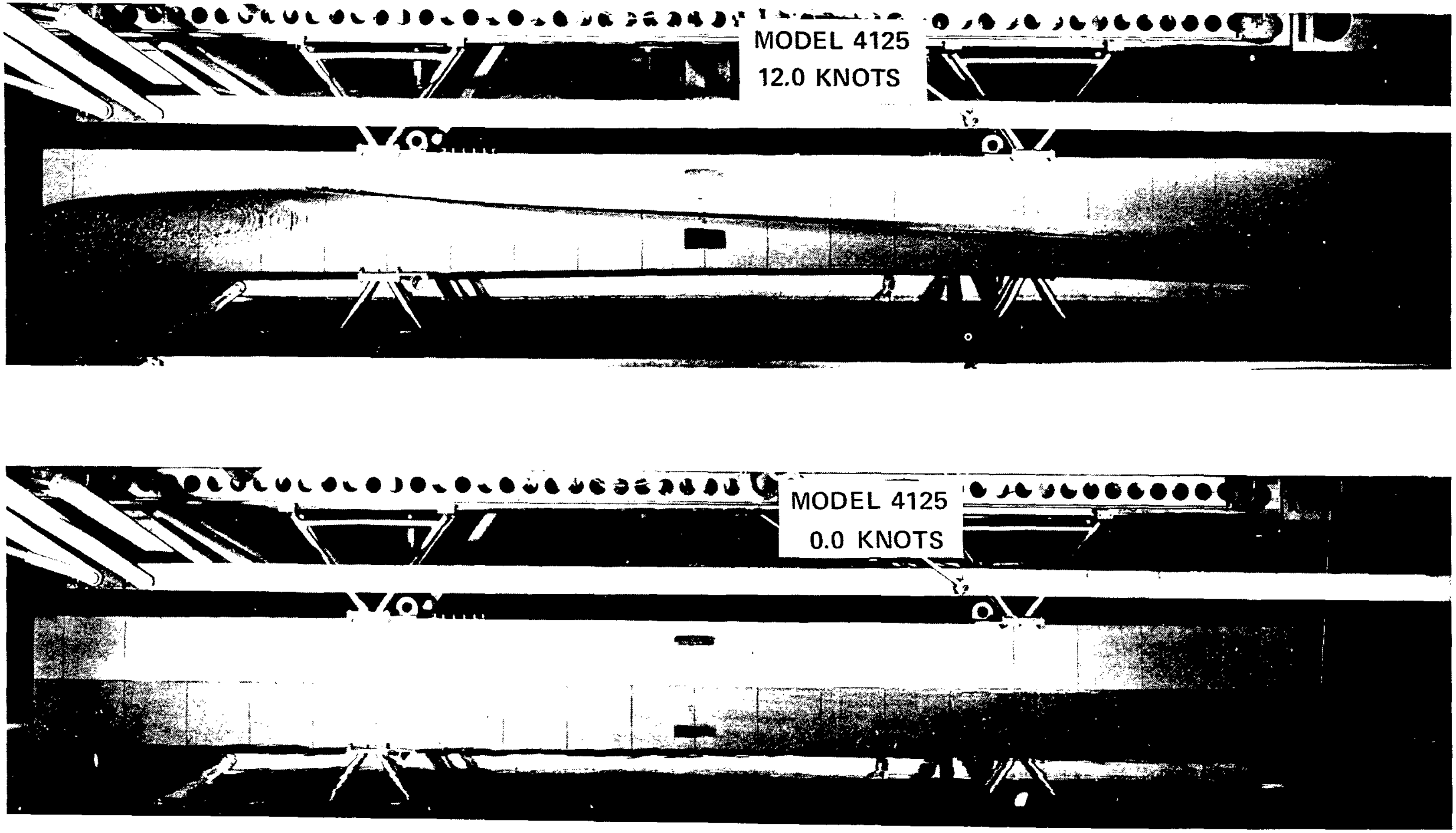


Figure 2 – NSRDC Friction Plane at Rest and under Tow

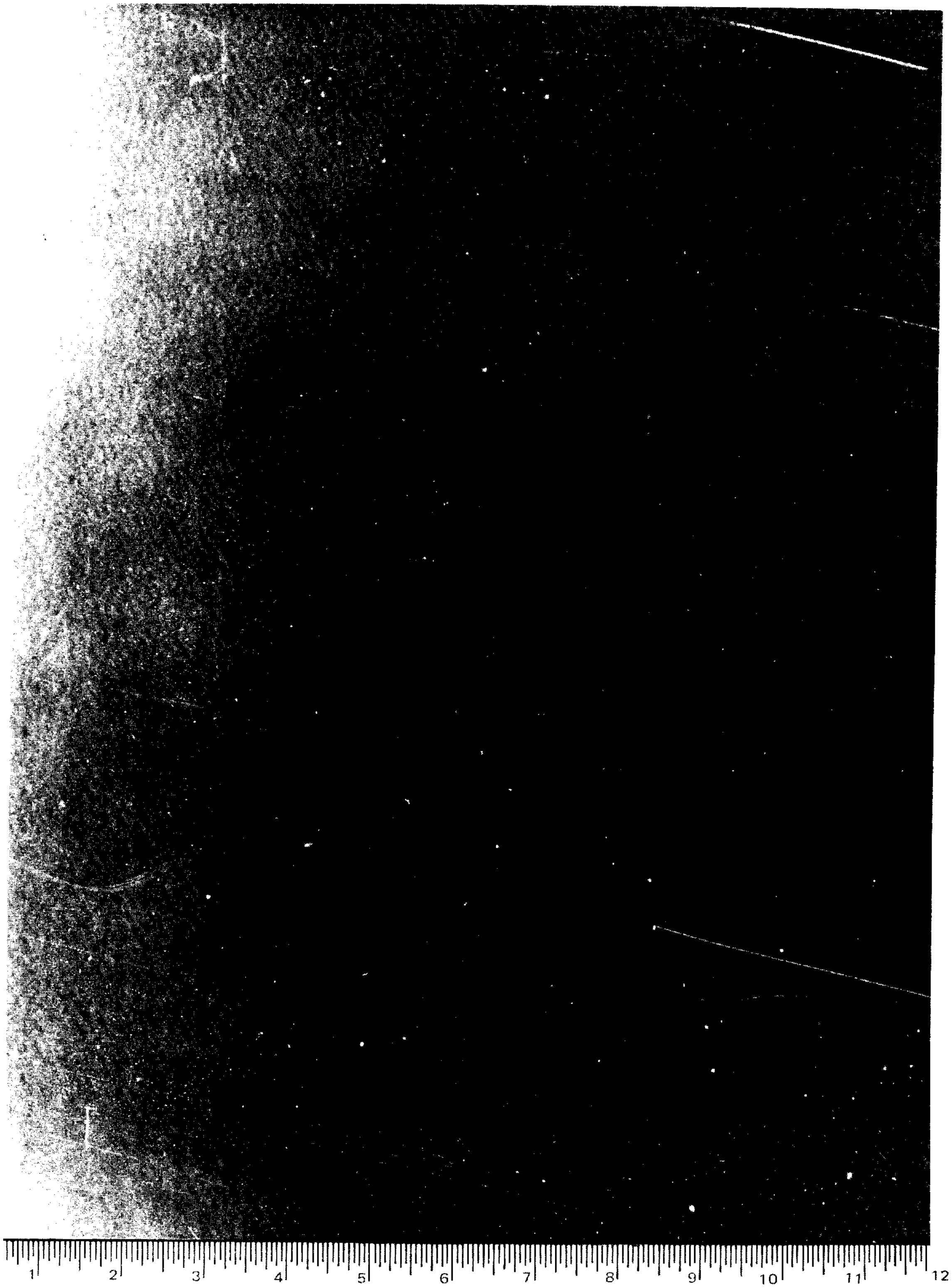


Figure 3 – Surface Finish of MARAD Paint on Friction Plane

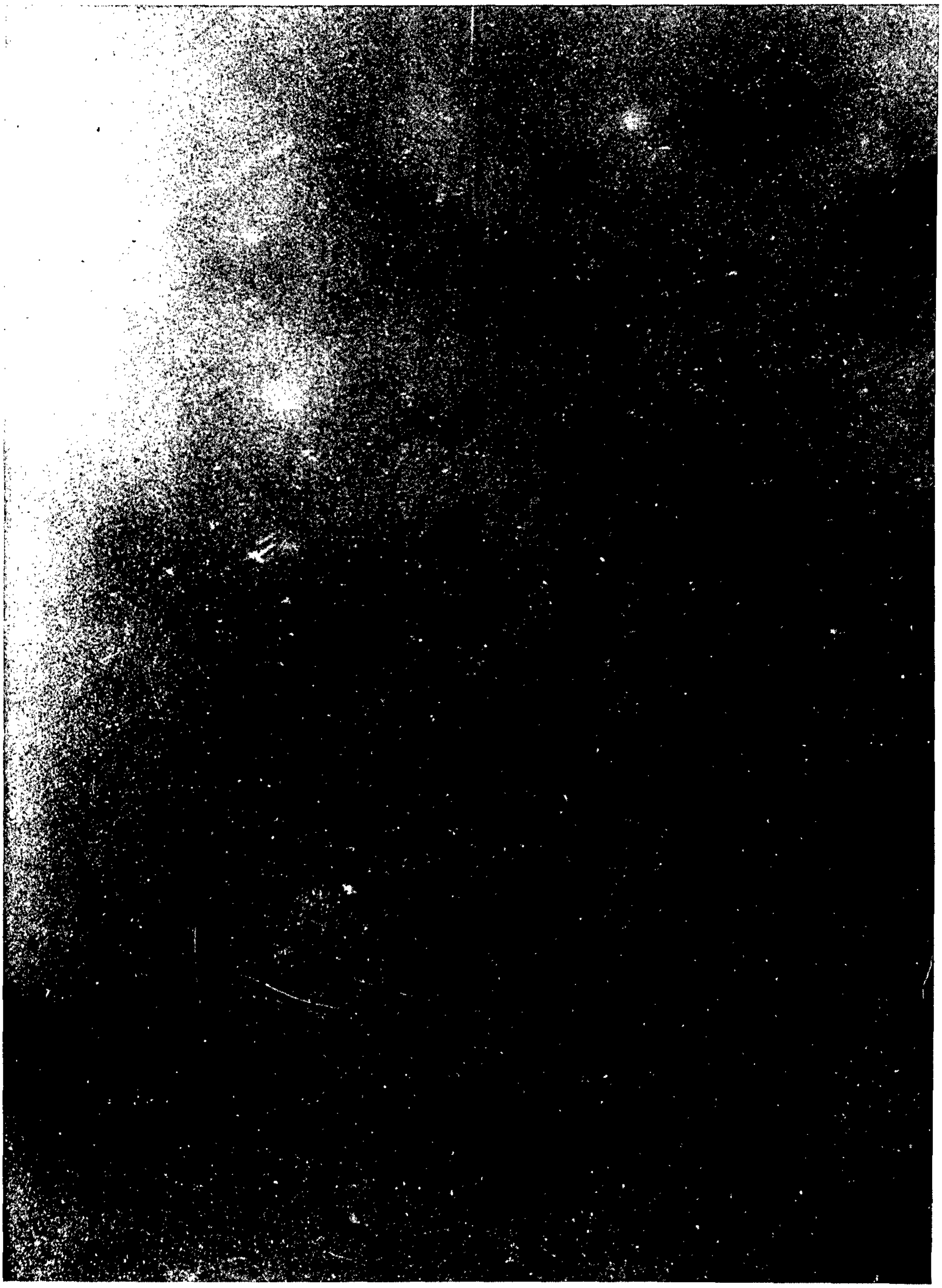


Figure 4 – Surface Finish of Navy Vinyl Paint on Friction Plane

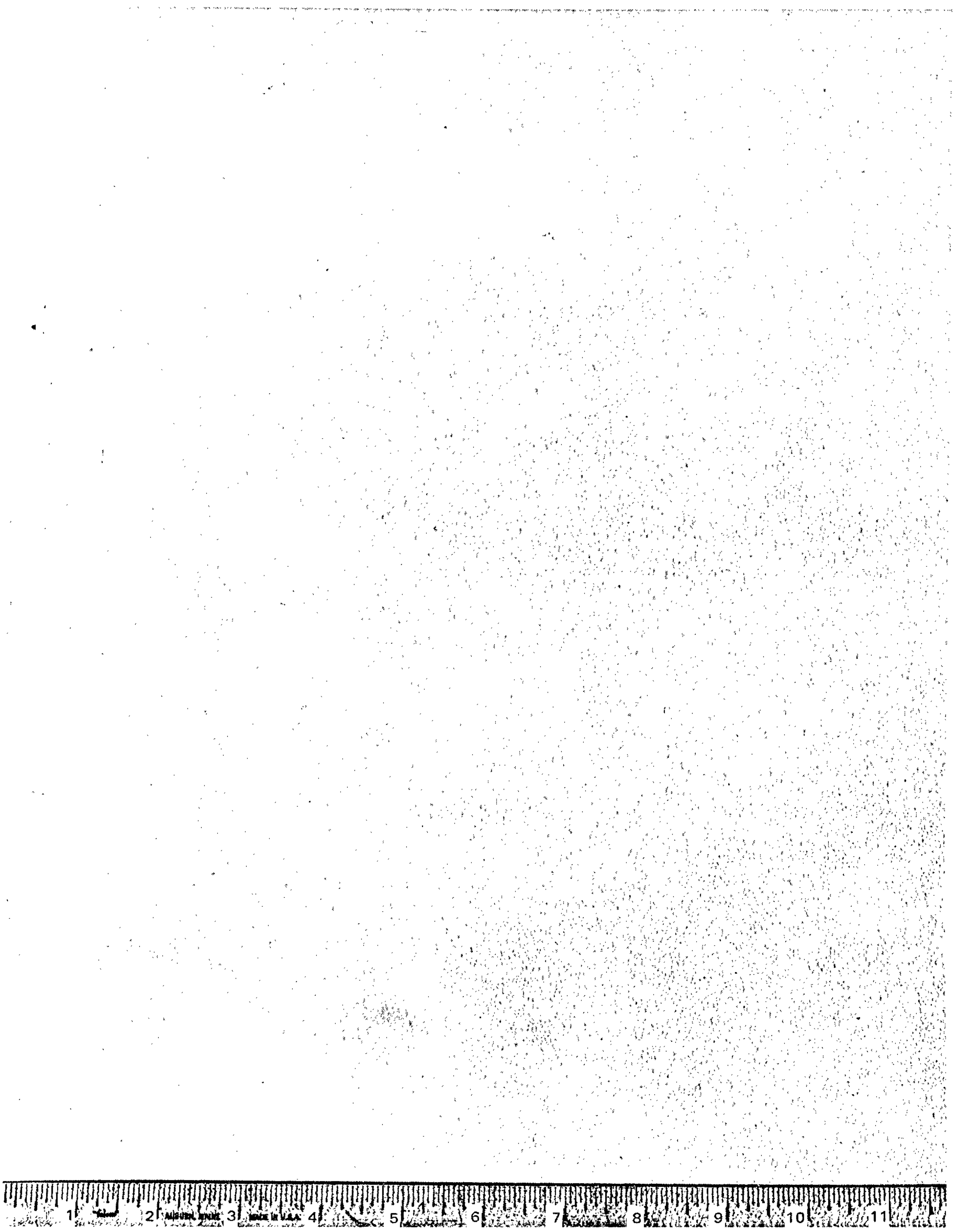


Figure 5 – Surface Finish of NSRDC Model Paint on Friction Plane

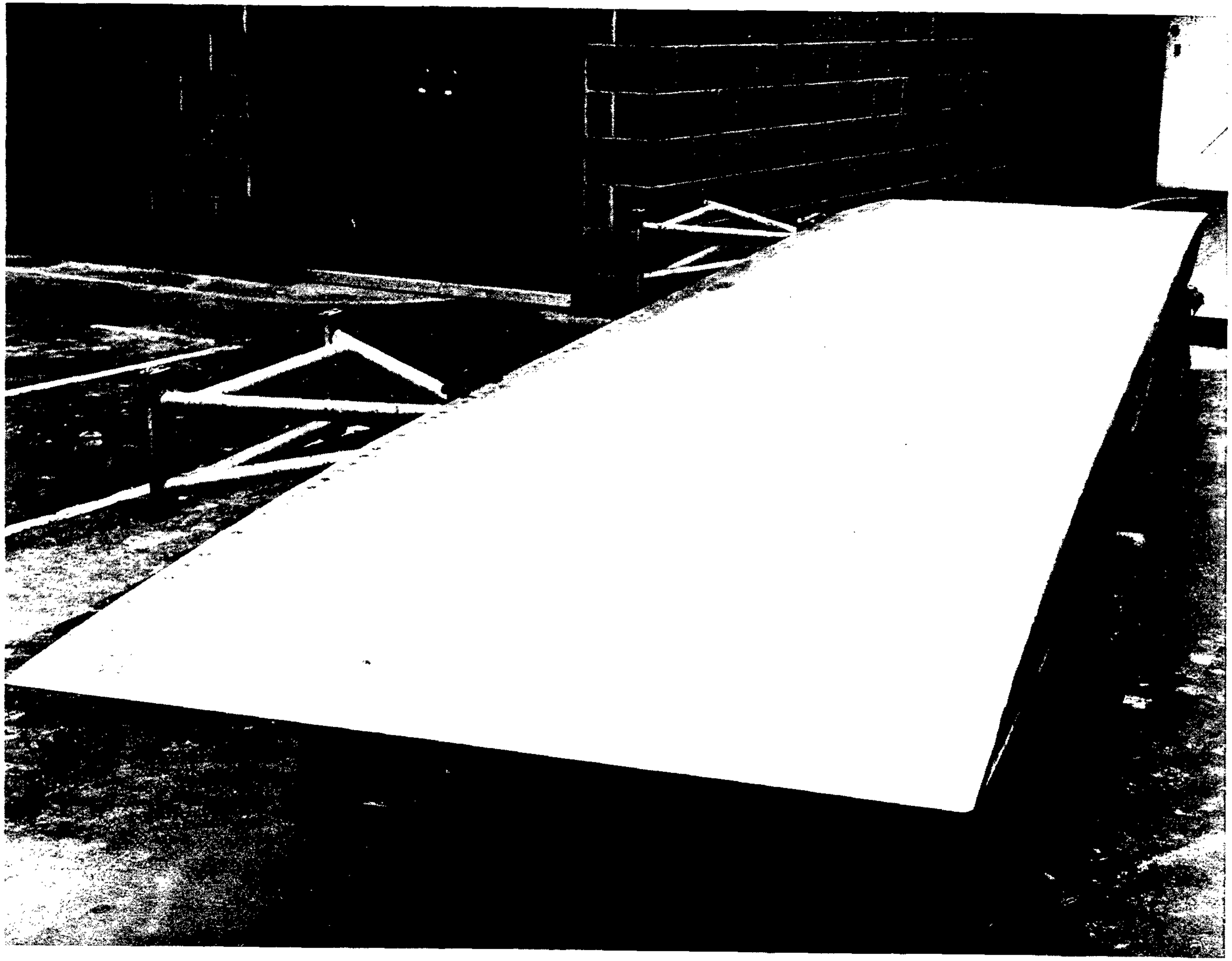


Figure 6 – Friction Plane Fitted with Fiberglass Plates

Figure 7 – Plate A–as Taken from the Hull

Figure 8 – Plate B—after Normal Treatment for Annual Drydocking

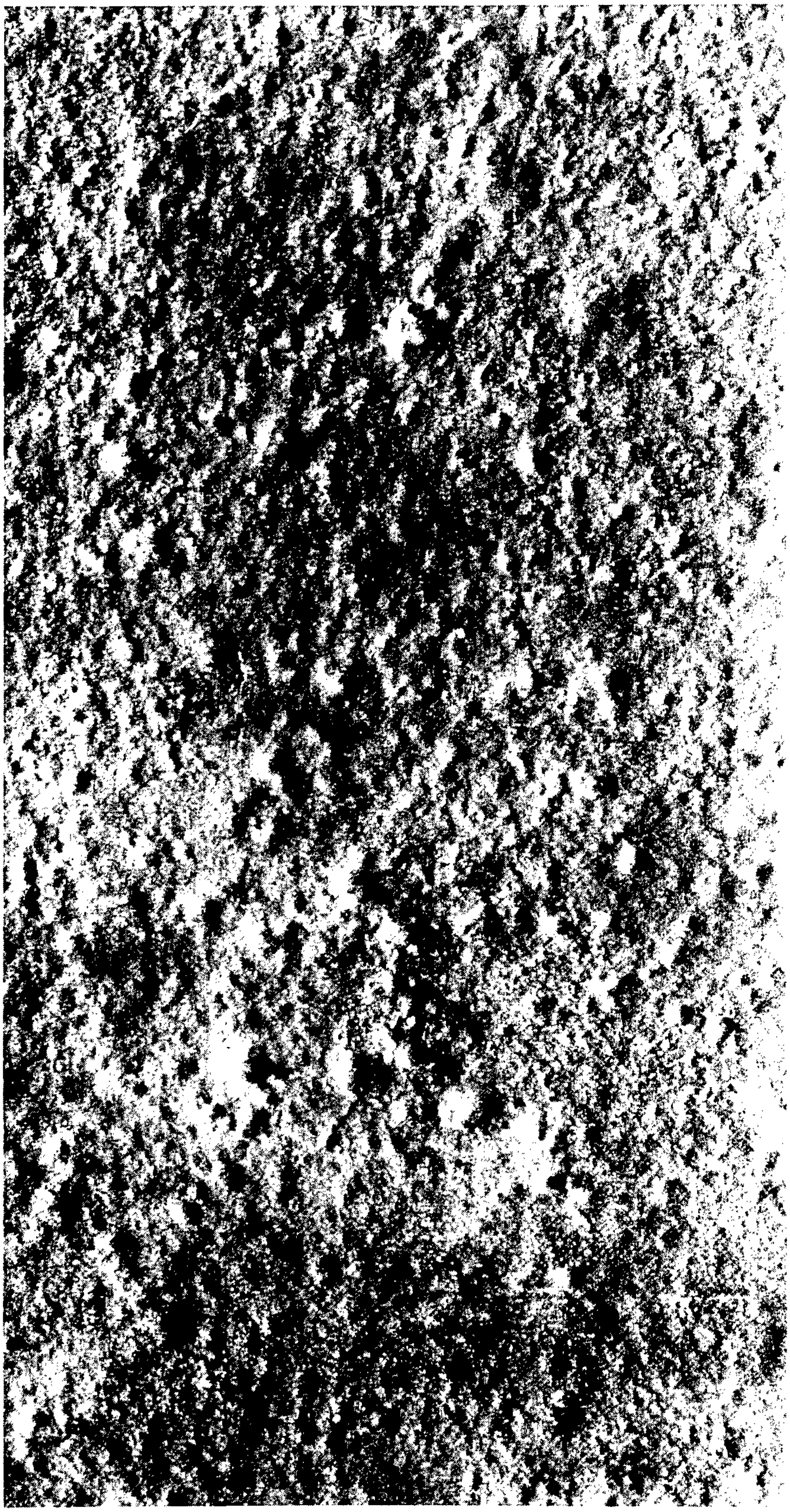


Figure 9 – Plate C—after Special Treatment

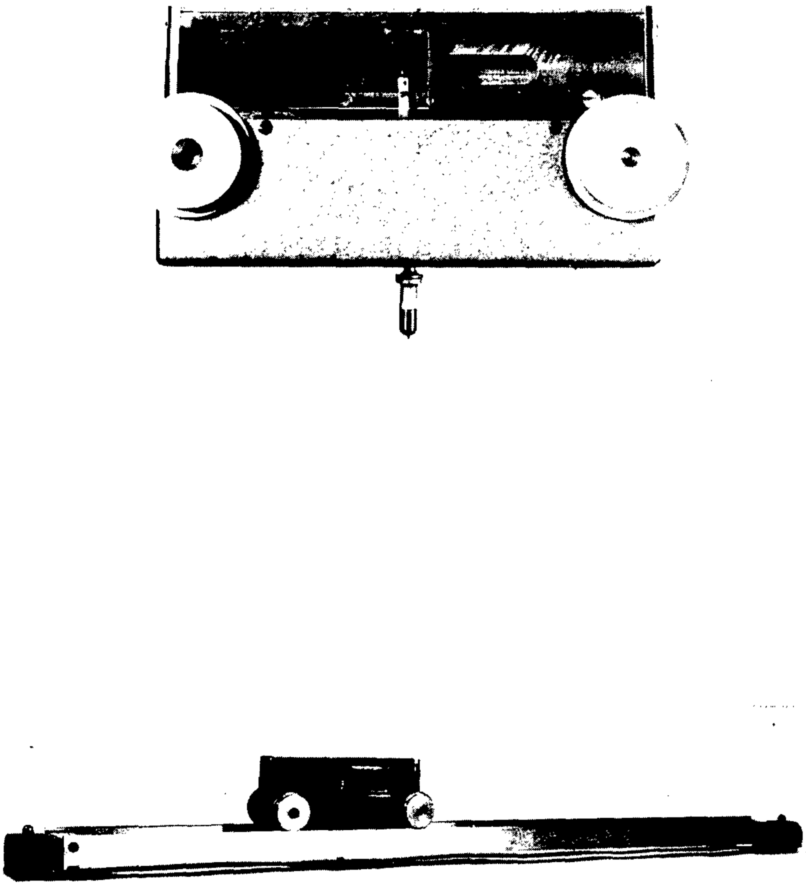
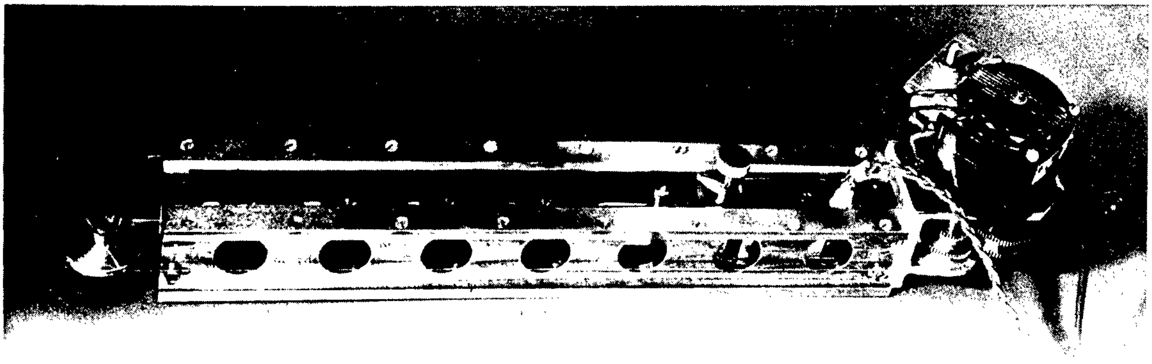
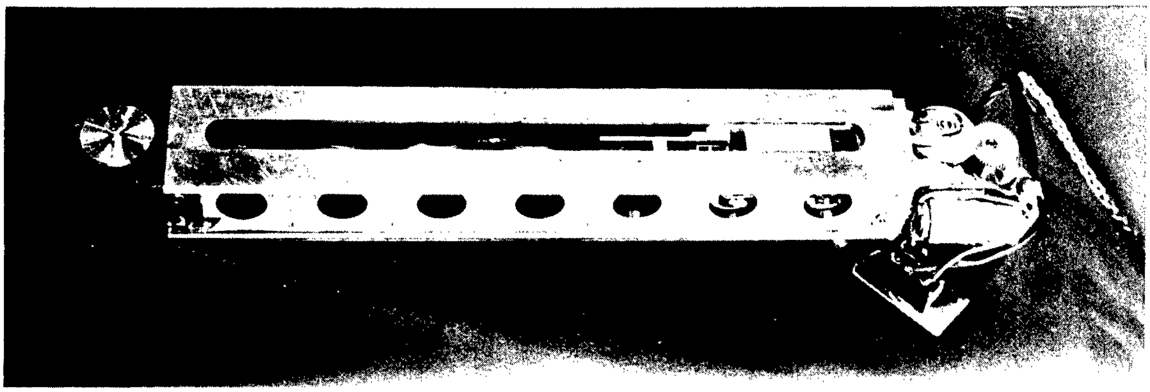


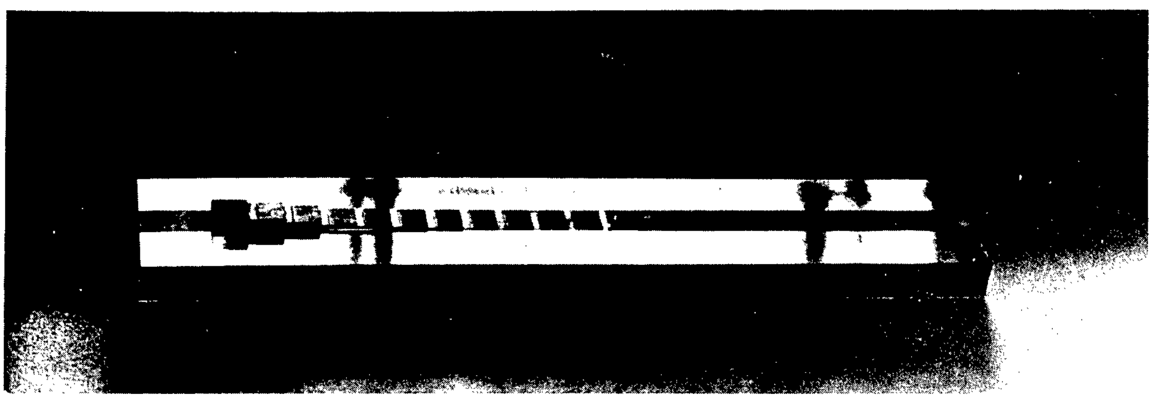
Figure 10 – BSRA Profilometer



RECORDING POSITION



PROBE MECHANISM SHOWING



CALIBRATION BLOCK

Figure 11 – NSRDC Profilometer

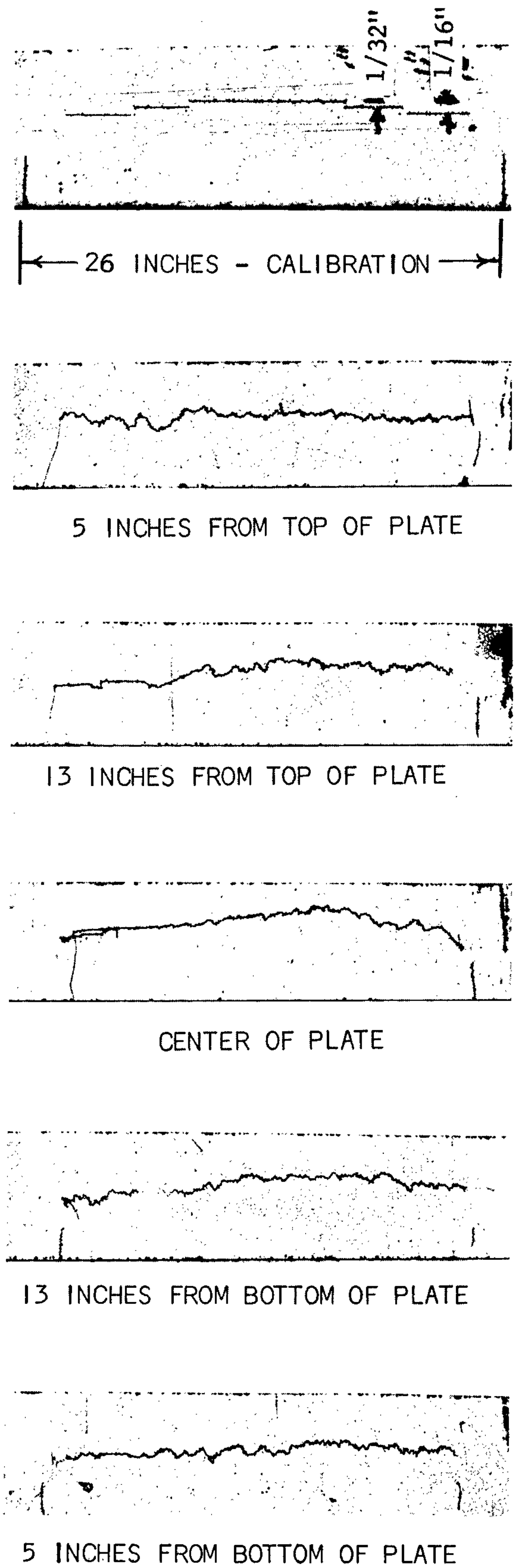


Figure 12 – Surface Roughness of Plate A as Measured with BSRA Profilometer

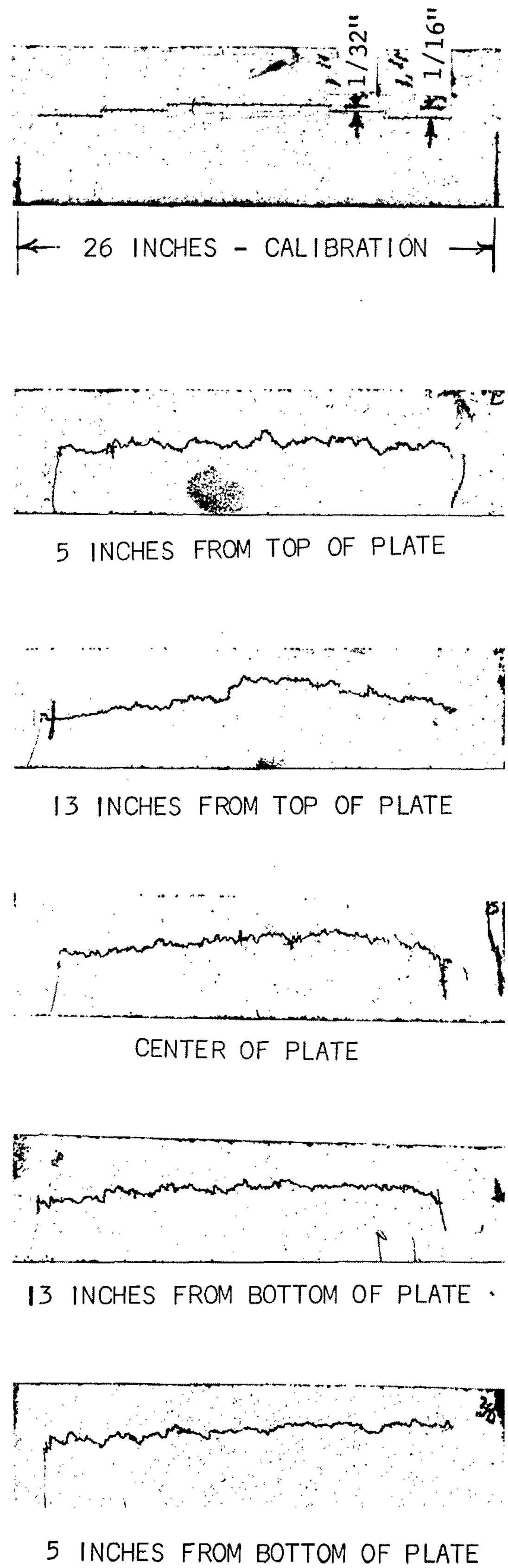
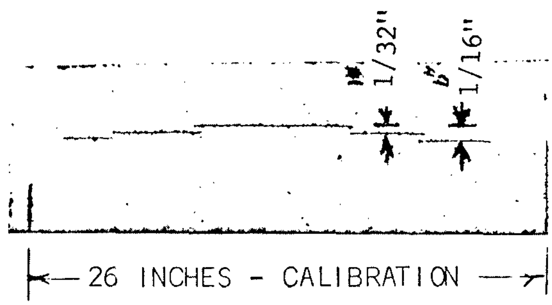
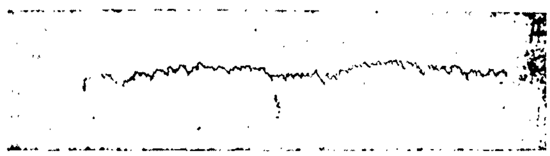


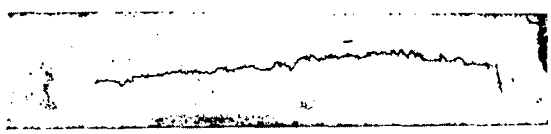
Figure 13 – Surface Roughness of Plate B as Measured with BSRA Profilometer



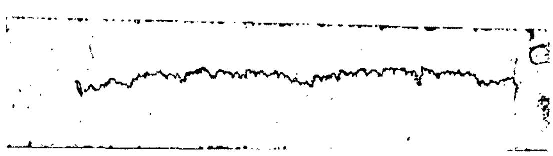


5 INCHES FROM TOP OF PLATE

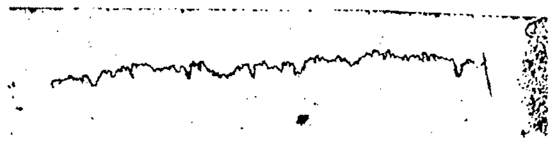
13 INCHES FROM TOP OF PLATE



CENTER OF PLATE



13 INCHES FROM BOTTOM OF PLATE



5 INCHES FROM BOTTOM OF PLATE

Figure 14 – Surface Roughness of Plate C as Measured with BSRA Profilometer

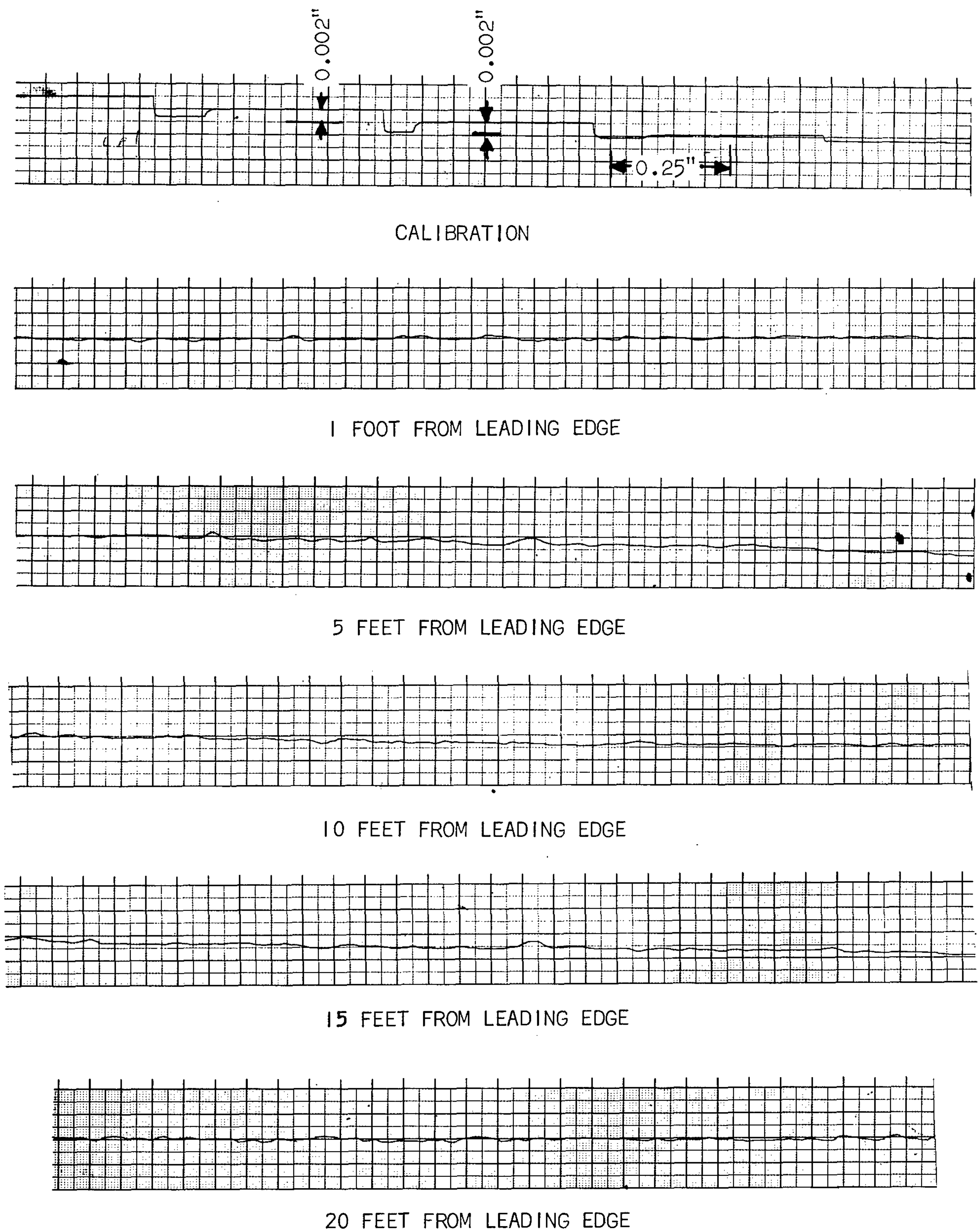
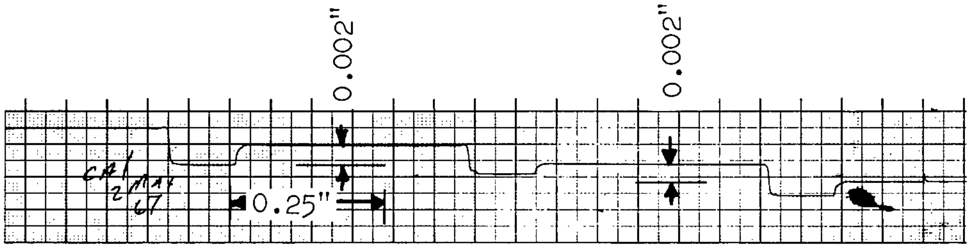


Figure 15 – Surface Finish of MARAD Paint as Measured with NSRDC Profilometer



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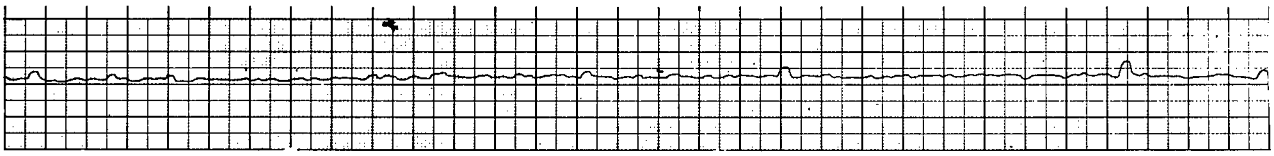
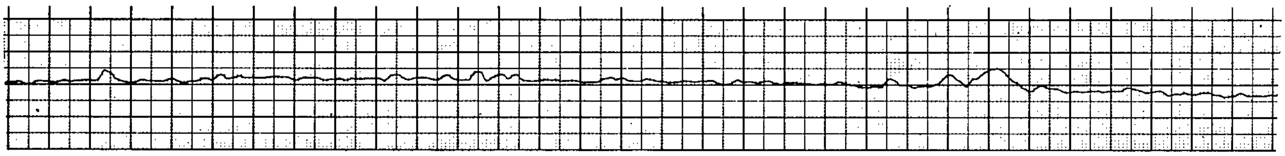


1 FOOT FROM LEADING EDGE



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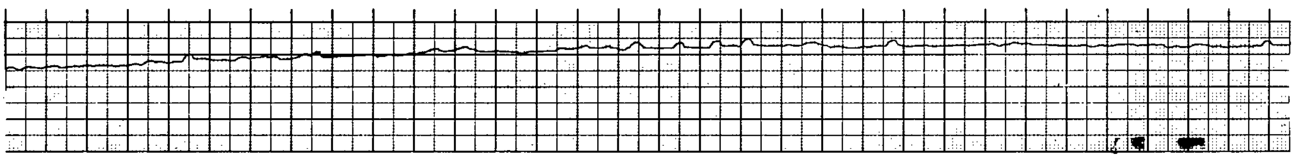
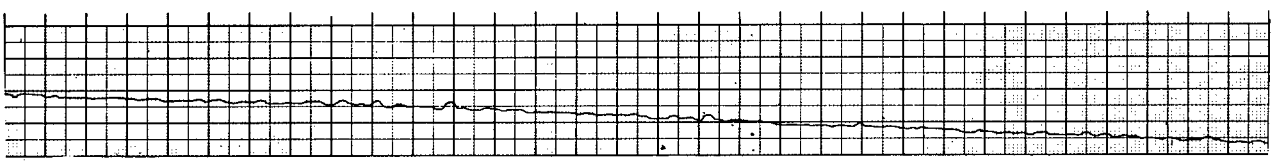
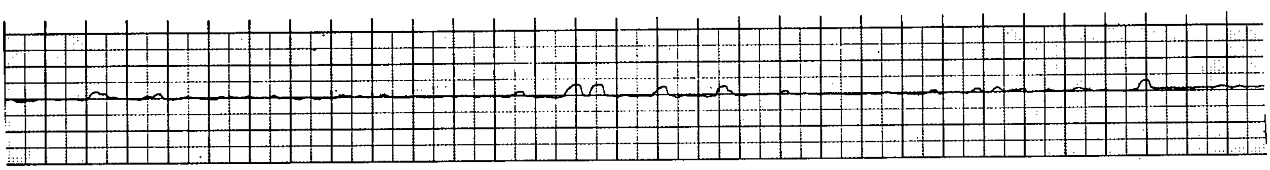


10 FEET FROM LEADING EDGE



15 FEET FROM LEADING EDGE



20 FEET FROM LEADING EDGE

Figure 16 – Surface Finish of Navy Vinyl as Measured with NSRDC Profilometer

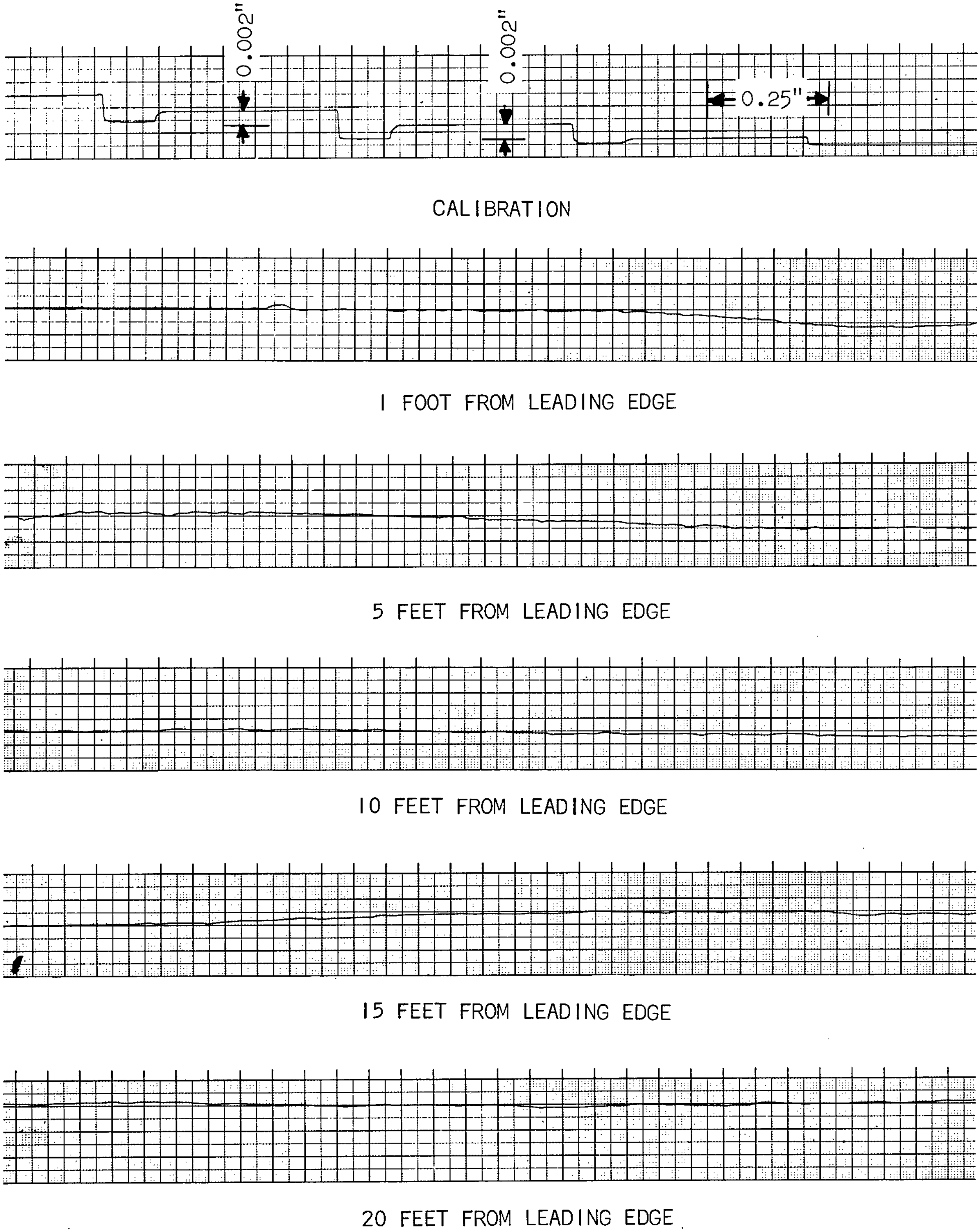


Figure 17 – Surface Finish of NSRDC Model Paint as Measured with NSRDC Profilometer

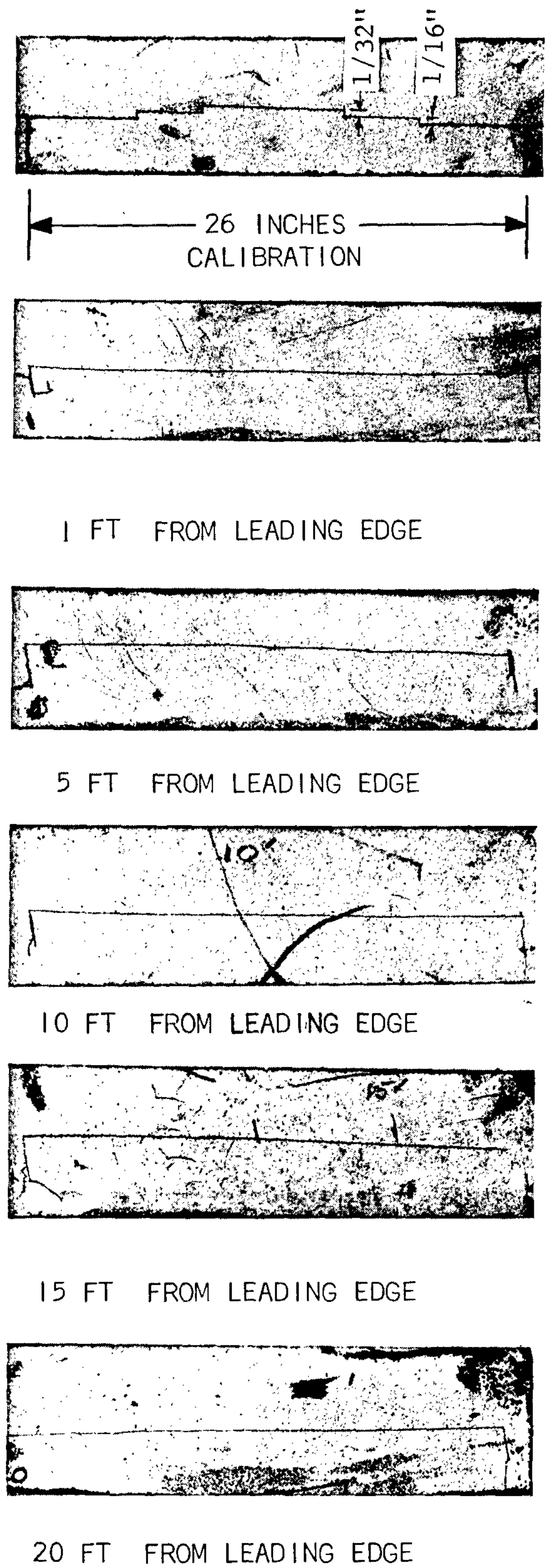


Figure 18 – Surface Finish of Navy Vinyl as Measured with BSRA Profilometer

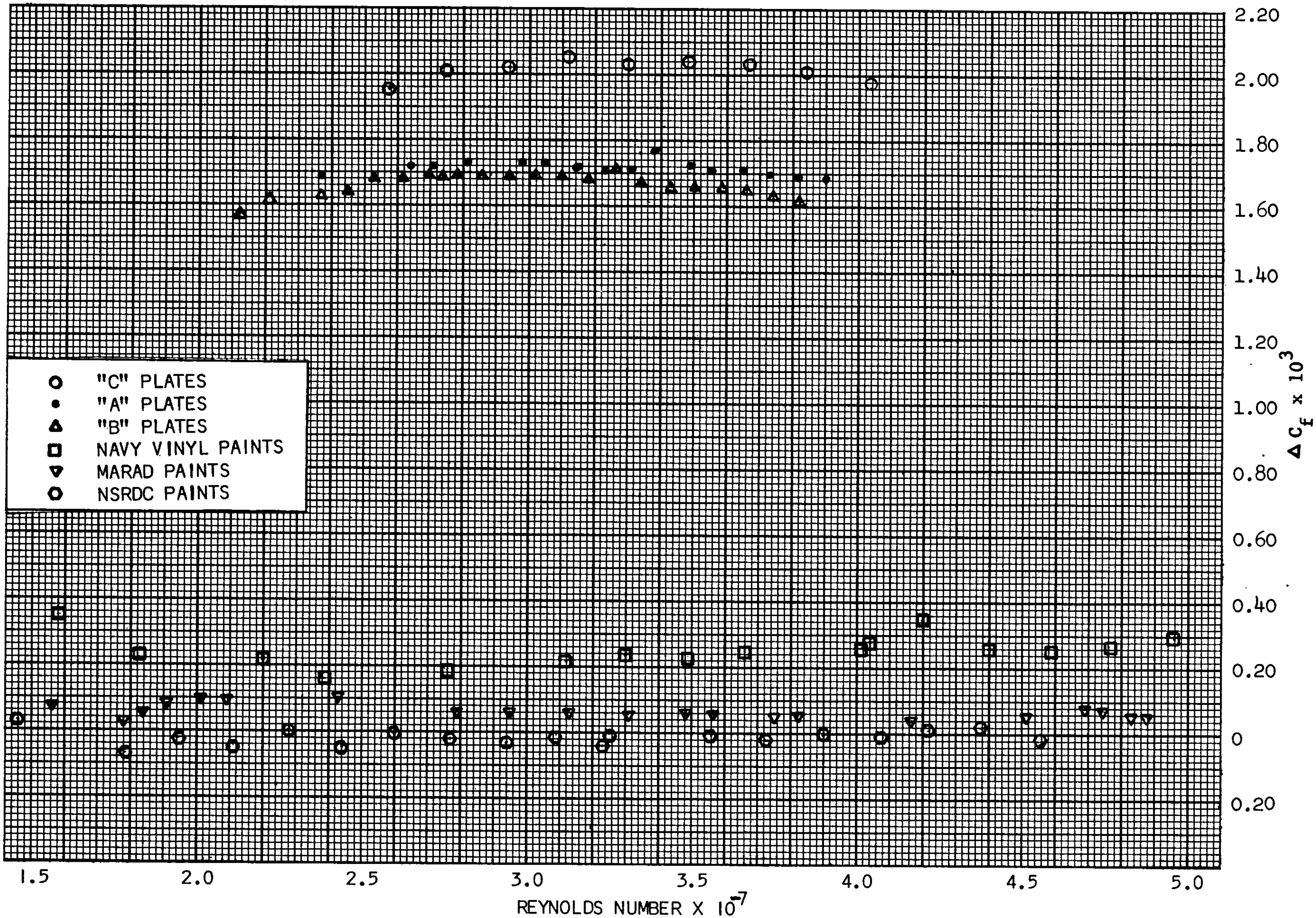


Figure 19 – ΔC_f versus Reynolds Number

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13. ABSTRACT

The Naval Ship Research and Development Center utilized a friction plane (NSRDC Model 4125) to estimate the differences in frictional resistance of two types of antifouling paints and of old ship bottom plates in three surface conditions. Photographs and roughness measurements are included for each surface investigated together with experimental data expressed as values of roughness allowance coefficient versus Reynolds number.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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Roughness Allowance						
Navy-Hull Paint						
Maritime						
Navy						
Friction Plane						